Biological Evaluation

R2-04-01

EVALUATION OF THE DOUGLAS-FIR BEETLE ON THE SHOSHONE NATIONAL FOREST, WYOMING

NOVEMBER 2003

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ABSTRACT

Douglas-fir beetle (*Dendroctonus pseudotsugae*) infestations frequently result from disturbance events that create weakened Douglas-fir (*Pseudotsuga menziesii*) trees near susceptible stands. Fires in 1988 occurred in Yellowstone National Park and the Shoshone National Forest. Populations of Douglas-fir beetle attacked and increased in fire scorched trees. Subsequent generations of the beetles moved from these injured trees to undamaged trees in neighboring stands on the Shoshone National Forest, Wyoming.

This outbreak has moved from the Clarks Fork/Sunlight Basin area and now affects almost the entire drainage west of Cody,WY along the North Fork and South Fork of the Shoshone River. The infestation has now spread into Douglas-fir stands on the Wind River RD, in the Wiggins Fork area outside of Dubois, WY. Beetle populations have increased in the past few years killing thousands of Douglas-firs. Field surveys indicate continued increasing Douglas-fir beetle populations. Because the current outbreak will continue to expand and intensify, continued high levels of mortality can be expected along the North Fork, South Fork, and perhaps, the greatest increases are expected to occur in the Wiggins Fork area.

Deployment of anti-aggregation pheromone has successfully protected Forest Service developed recreation areas for three years. These pheromones have also been used successfully around summer homes and lodges. Continued use of anti-aggregation pheromones and sanitation harvest is recommended.

INTRODUCTION

The Douglas-fir beetle, *Dendroctonus pseudotsugae* Hopkins, infests and kills Douglas-fir (*Pseudotsuga menziesii*) throughout its range in North America. Typically, the beetle reproduces in scattered trees that are highly stressed, such as windfall, defoliated or fire-scorched trees (Furniss 1962; Furniss 1965; Lessard and Schmid 1990). If enough suitable host material is present, beetles can increase in the stressed trees and infest nearby healthy trees (Furniss et al. 1981). Previous research on Douglas-fir beetle infestations have examined forest stand and site characteristics associated with infestations (Furniss et al. 1979; Furniss et al. 1981; Weatherby and Thier 1993; Negron 1998) and developed models to predict the extent of tree mortality (Negron et al. 1999). Douglas-fir beetle attacks are most successful on older, larger trees found in high-density stands that contain a high percentage of Douglas-fir in the overstory (Schmitz and Gibson 1996).

The Douglas-fir beetle (DFB) has one generation per year (Schmitz and Gibson 1996). Although adult flight times vary by year, most new attacks occur in late spring to early summer on the Shoshone National Forest. Broods develop under the bark throughout the summer and early fall. The overwintering life stage can be as adults, pupae or larvae. Larvae that overwinter complete their development and emerge as adults later in the summer. A small percentage of adults that over wintered will re-emerge from the spring-attacked trees and attack additional trees in the middle of the summer.

Fires that started in Yellowstone National Park in 1988 burned onto the Clarks Fork Ranger District of the Shoshone National Forest, Wyoming, killing and scorching a large number of trees. Populations of the DFB increased in scorched trees and began attacking neighboring green trees in this area. Similar events took place within Yellowstone National Park (Rasmussen et al. 1996). Beetle populations have now started to severely impact Douglas-fir stands along both the North Fork and South Fork of the Shoshone River over the past 5 years. Also, in 2002, an increase in DFB mortality was noted in the Wiggins Fork area outside of Dubois, WY. It has been 15 years since the fires that started the initial DFB outbreak. At this point it is difficult to tell for sure whether or not the ongoing outbreak is still a result of that event. Typically, DFB outbreaks do not last for this extended period of time, however, all indicators are that tree mortality is still increasing.

This DFB infestation has obviously impacted forest stand conditions over the last decade (McMillin and Allen 2000). A predictive mortality model was developed based on the infestation (Negron et al. 1999). Most of the recent mortality has occurred along the North Fork of the Shoshone River (Allen and Long 2002). This is a scenic byway and heavily used travel corridor, leading to the east gate of Yellowstone National Park.

Over the last 2 years, sanitation efforts to remove infested trees occurred in and around administrative units along the North Fork. Also, deployment of MCH (3-methylcyclohex-2-en-1-one), an anti-aggregation pheromone, has been used to protect uninfested trees in high value areas. This technique has been shown to be highly effective at reducing tree mortality (Ross and Daterman 1994, 1995; Ross et al. 2001).

MATERIALS AND METHODS

Pheromone Trapping

Funnel traps baited with a 3-component synthetic Douglas-fir beetle aggregation pheromone were deployed and checked every 2 weeks.

Traps were deployed in late April, 2003, two per site. Six sites were installed in the Clarks

Fork/Sunlight Basin area and six sites installed along the North Fork of the Shoshone River. Traps were checked for the first time on 14 May and maintained until 17 September, 2003.

Brood Sampling
On August 13, 2003, in the Wiggins Fork area, and October 1, 2003 along the North fork 6 inch by 6 inch bark samples were removed from the north and south sides of Douglas-fir trees currently infested by DFB. 20 trees were sampled in the Wiggins Fork area and 15 along the North Fork. Sample height was 5 – 7 feet above the ground. Diameter at breast height was recorded for each sampled tree. Measurements taken for each sample included the following: number and life stage of live DFB, number of DFB gallery starts, and number of each of three groups of DFB natural enemies: beetles, wasps and flies.

Field Transects
Transect lines were run in the Wiggins Fork area in August, 2003. Transect lines were run along the North Fork in July and August 2003. Transect lines ranged from 0.25 to 1.75 miles in length and were 1 chain wide, covering an area of 2 acres per quarter mile of line. Recently killed trees were tallied along each transect line. Attacked trees were broken into three categories: new beetle hits (year 2003 green attacked trees), one-year-old hits (2002), and two-year-old hits (2001).

Eight transect lines were run, covering 5.25 miles throughout the two areas, for a total of 42 acres evaluated. On each line, 20th acre fixed radius plots were measured every ¼ mile. Diameter at breast height (DBH) was taken for all in trees in each plot. These measurements were used to provide an estimate of diameter at breast height (DBH) and trees per acre (TPA) along the transect lines.

Use of Anti-aggregant Pheromone MCH
On April 23, 2003, bubble capsules containing the DFB anti-aggregant pheromone MCH were stapled to trees in the Newton Creek, Eagle Creek and Clearwater Campgrounds according to prescribed methods (Ross et al. 2001). The density deployed was 30 capsules per acre.

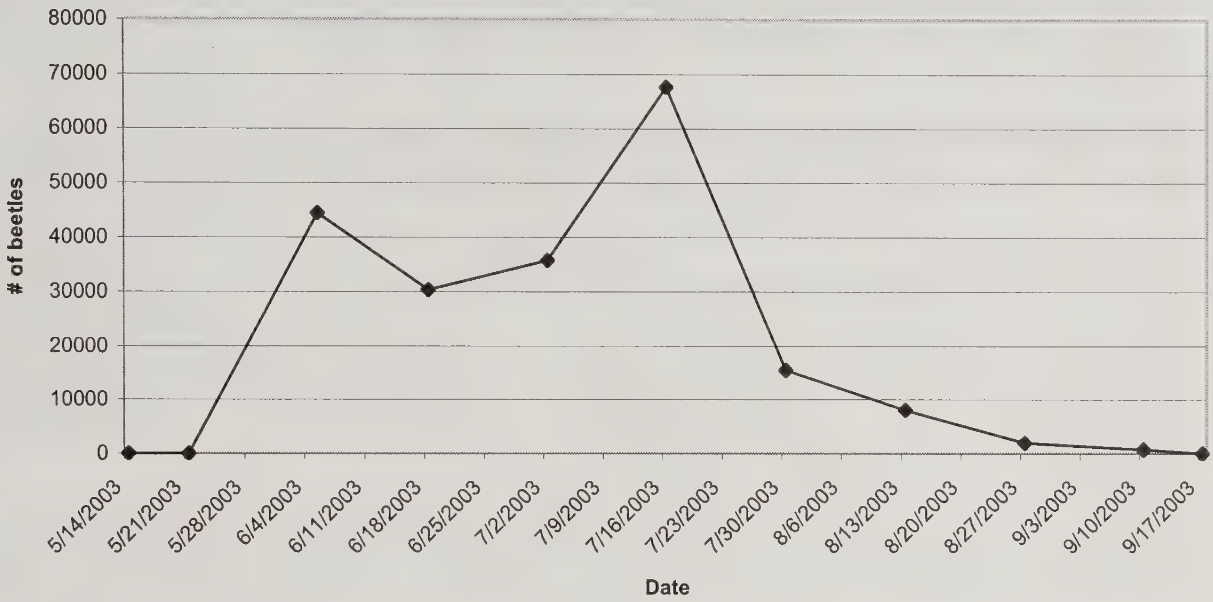
On 18 September, bubble capsules were removed and the treated areas completely surveyed for DFB activity.

RESULTS AND DISCUSSION

Pheromone Trapping
Numbers of DFB recovered from the two traps at each location were combined. Trap catch data from each location in each of the two areas were examined. The overall trend and timing of DFB catch was very similar among locations for both areas, therefore, all data have been combined. Trap catches are used to monitor and determine the approximate timing of DFB flight and attack.

Figure 1 shows the flight period of DFB in this area. No beetles were caught until late May, then there is a peak in early June, followed by consistent catches until the final, and largest peak in mid July. It is apparent from the flight period that most of the new attacks had occurred by early August in 2003.

Figure 1. Total biweekly Douglas-fir beetles caught in pheromone traps on the Shoshone NF



Timing of flight is important in outlining management actions. If MCH is to be used in protecting trees, it needs to be deployed prior to mid May when flight begins. Any sanitation removal should also be complete by this time. Checking for new infestations for possible removal can begin in mid August. Typically, flight times will not vary much, but can be 2-3 weeks earlier or later depending on weather factors. Hence the guidelines above, particularly the placement of anti-aggregation pheromones, should be adjusted accordingly.

Brood Sampling

At Wiggins Fork all of the DFB found in the brood samples were eggs or larvae, while at the North Fork, over 98% were new adults. This is mostly a factor of the sampling times. Wiggins Fork was done about 2 months prior to the North Fork. It is assumed that had the sampling been done about the same time, the life stages would have been the same.

There was no difference among overall brood averages between north and south samples at each sample area, so results were combined. Although the sample area was 0.25 ft^2 (36 in^2) of bark surface, results are reported on a per square foot basis (144 in^2) (Table 1).

Population trends can be estimated by dividing the density of new adult beetles by twice the density of gallery starts (attacks), assuming that a pair of beetles initiates each gallery start. The average density of new beetles represents the next generation, while the average density of attacking beetles represents the current generation. The ratio of the size of the two generations yields what is called a population trend ratio. When the ratio of new adult beetle density to attacking adult density exceeds one, the population is increasing, and when the ratio is less than one, the population is decreasing.

The population trend ratio at the Wiggins Fork is 11.8:1 for emergence to attack, indicating that the population is growing rapidly. The population trend ratio along the North Fork was 8.9:1 for

emergence to attack. Again, this indicates a strongly increasing beetle population going into 2004.

Natural enemies of DFB were rare in the samples, although the accuracy of these estimates is likely to be low. A resampling of these areas in the spring would likely give better natural enemy estimates.

Table 1. Average Douglas-fir beetle brood and natural enemy density per square foot of bark surface at two locations along the North Fork of the Shoshone River, Wyoming, on September 17-18, 2002. Averages are reported ± standard error of the average.

Variable	Wiggins Fork	North Fork
Number of Trees	20	15
Number of Samples	40	30
Average Tree Diameter	18.3 inches	17.5 inches
Total Brood	142.7 ± 59.9	107.1± 36.8
Egg Gallery Starts	12.2 ± 4.9	12.9 ± 5.0

Maximum brood production takes place when gallery starts average between 4 and 8 per square foot (McMullen and Atkins 1961). This is the case for both sample sites (Table 1), as it was last year, providing additional evidence of a large, healthy DFB population in the area.

The values for total brood per square foot, gallery starts per square foot, and the population trend ratio are all increase over what was found last year (Schaupp et al 2003).

Field transects

Table 2 lists the number of attacks by transect line in both the Wiggins Fork and North Fork areas, and corresponding number of attacked trees by year, average DBH, TPA, trees per acres killed and 5 of trees per acre killed. Much of the mortality along the North Fork is evenly distributed between currently infested trees and trees killed 1 and 2 years ago. Generally speaking, in the North Fork area the outbreak is leveling out somewhat, largely due to the fact that a suitable food source is running out for the beetles. Many of the stands in this area are approaching 50% or greater mortality in the stand and the outbreak is not over. It is not out of the question that by the time the beetle outbreak subsides, 75% or greater of the area will be killed. It will likely be 80-100 years before there is anything resembling a mature Douglas-fir forest in this area again. In the Wiggins Fork area, where the beetle is just getting started, there are far more currently infested trees than there are 1-year-old killed trees. There is a population buildup of about 6.5:1 from 2002 to 2003 in this area. This certainly indicates that the beetle population in this area is rapidly growing. The average tree DBH per transect line ranged from 9.4 inches to 12.6 inches across the two areas. This number is perhaps somewhat lower due to the use of fixed radius plots, where trees down to 3 inches DBH were counted. The average trees per acre ranged from 152 to 260. In most cases this is comprised almost entirely of Douglas-fir. This combination of tree size and stand density provide suitable habitat for beetle infestation. Additionally, having these conditions occur over such a large and contiguous area lends itself to the continuation of a large-scale beetle epidemic.

Predicting beetle spread and cumulative mortality over the course of an outbreak is difficult. The amount of tree mortality from our transect lines is a conservative estimate in that only mortality that has occurred in the last three years was accounted for and the outbreak is by no means over. Based on the last three years, however, mortality on a transect lines ranged from 5-58% of the average trees per acre.

Table 2. Results by transect of ground surveys done in the Wiggins Fork and North Fork areas, 2003.

Transect	Location	CY*	1yr**	2yr***	Total	DBH	TPA	Trees Killed/Acre	% TPA KILLED
1	Wiggins Fork	239	18	6	263	12.2	250.0	32.9	13.2%
2	Wiggins Fork	85	32	31	148	10.3	200.0	37.0	18.5%
1	North Fork	7	28	7	42	9.7	220.0	10.5	4.8%
2	North Fork	108	18	4	130	11.6	160.0	65.0	40.6%
3	North Fork	114	250	70	434	12.6	152.0	31.0	20.4%
4	North Fork	152	283	169	604	10.0	260.0	151.0	58.1%
5	North Fork	51	3	0	54	9.4	240.0	27.0	11.3%
6	North Fork	179	24	259	462	11.7	260.0	115.5	44.4%
Sum		**935**	**656**	**546**	**2,137**				
Average		**109.8**	**24.0**	**12.0**	**146**	**10.9**	**217.8**	**36.3**	

*CY= Current year (green) infested trees, *1yr=Red needled, 1 year old dead trees,*2yr=Needles mostly gone, 2 year old dead trees

Use of Anti-aggregant Pheromone MCH

No new DFB attacks were found at any of the treated Forest Service campgrounds. MCH has proven to be very effective at protecting trees and stands when properly deployed. Very few host trees have been lost in the campgrounds where MCH has been used, even as the beetle populations and tree mortality surrounding the campgrounds has increased.

CONCLUSIONS

An extensive outbreak of Douglas-fir beetle is in progress that could potentially affect all Douglas-fir forests on the Shoshone National Forest. Brood survey data field observations indicate that this beetle outbreak will continue to increase in size and intensity. Barring unanticipated high levels of overwintering and dispersal mortality in the DFB population, an increase in Douglas-fir mortality is likely next year across the North Fork and South Fork drainages west of Cody and in the Wiggins Fork area outside of Dubois. Based on the continuing growth of the ongoing outbreaks and the expansion of beetles into new areas, any mature Douglas-fir stands on the forest should be considered to be at risk.

If no management actions are implemented, there will be further reductions in Douglas-fir overstory and average tree diameter across the landscape. Results from the Clarks Fork portion of this DFB outbreak estimate that Douglas-fir basal area will be reduced by 55 to 78 percent (Negron et al. 1999). In addition, the average size of trees will be reduced for the next 100 to 200 years. Regeneration and herbage production will increase in beetle-caused openings in the forest. Annual streamflow and water yield may increase where the outbreak occurs. The visual impact is will continue to be very noticeable. In addition, the red needles provide a temporary increase in dry, fuels in the canopy. When the dead trees begin to fall down, coarse woody debris and large fuels will increase. The majority of the regeneration will continue to be Douglas-fir, with smaller percentages of spruce, fir, and pine.

MCH has proven to be very effective at protecting uninfested trees from DFB.

In areas where land management objectives are threatened by mortality of mature Douglas-fir, actions can be taken that protect individual trees, groups of trees or stands. Silvicultural treatment would likely to help reduce future mortality from DFB by altering the conditions that favor the beetles. Concerns now should focus on how to maintain what is left of the current Douglas-fir overstory and how to prevent landscape scale outbreaks such as this in the future.

BEETLE MANAGEMENT STRATEGIES

Strategy 1: Silvicultural treatments
This is the only long-term strategy that addresses the cause of DFB outbreaks, which is susceptible trees and stands. Silvicultural treatment should be part of any ongoing vegetation management program to help increase the health of stands by decreasing their susceptibility to insects and diseases. Factors that weaken tree defense, such as overcrowding and overmature trees, homogenous stand conditions, and environmental factors such as drought or fire, can predispose an area to bark beetle beetle outbreaks. Silvicultural treatment to reduce susceptibility to and reduce mortality before or during beetle attack. To reduce the susceptibility of stands to Douglas-fir beetle, basal area should be brought below 80% of normal stocking (Furniss et al. 1981). Harvesting in old, mature stands and thinning in dense younger stands should lower individual stand susceptibility to Douglas-fir beetle attack.

Trees become susceptible to the Douglas-fir beetle when the combination of stand density and tree size begins to exceed the carrying capacity of the site for water and nutrients (Shore et al. 1999). The proportion of Douglas-fir in a stand and its density are important regulators of susceptibility (Furniss et al. 1981; Negron 1998; Negron et al. 1999). In unmanaged stands, beetles attack older, larger trees in denser groups (Furniss et al. 1981). Silvicultural treatments that alter these stand conditions will reduce a stand's susceptibility and subsequent mortality (Schmid and Amman 1992; Schmitz and Gibson 1996).

The resistance of live trees to beetle attack is the most important natural factor controlling outbreak development (Schmitz and Gibson 1996). In addition to silvicultural treatments to reduce tree and stand susceptibility, treatment of trees that lose their resistance to attack is important in preventing outbreak induction. The Douglas-fir beetle most successfully breeds in trees injured by wind, disease, defoliation, fire or other agents. This increased reproduction allows populations to increase to levels where they can overwhelm and kill otherwise healthy trees.

Strategy 2: Beetle suppression
There are a number of methods that directly kill beetles. Direct control attempts are a short-term approach to beetle management, unlike silvicultural treatments.

Sanitation harvests involves removing currently infested trees from the site. Removal of beetle-infested trees can reduce the size of a local beetle population. To be effective, sanitation harvesting needs to be done before the beetles start to emerge in May of each year. Treatment may need to be repeated over several years, as some trees are always missed and immigration from untreated areas is possible. In stands where mortality is already significant, salvaging dead trees to capture some economic value is appropriate. However, salvage harvesting does not reduce beetle populations.

Currently infested trees can be located and treated mechanically to kill beetles developing within them prior to brood emergence. Non-commercial sanitation includes methods such as peeling

bark, chipping, burning, burying, or hauling infested trees at least one mile from the nearest host type.

Douglas-fir beetles are strongly attracted to down trees. Trap trees take advantage of this attraction by deliberately luring beetles to intentionally felled trees. Trap trees must fresh and once infested, they must be treated in some fashion to kill the beetles in them.

Strategy 3: Prevention of beetle attacks
Douglas-fir beetle has a well-studied complex of pheromones. Anti-aggregation pheromones, such as MCH (3-methylcyclohex-2-en-1-one), control the density of beetle attacks by disrupting the aggregation behavior of beetles (Schmitz and Gibson 1996). MCH has been used experimentally and operationally to reduce the level of attack in high-risk areas (Ross and Daterman, 1994, 1995; Ross et al. 2001). Several insecticides, such as carbaryl, are registered for use that can prevent infestation when applied properly prior to beetle attack. For large trees, specialized application equipment is needed.

RECOMMENDATIONS

1. Use of aggressive silvicultural treatments.

The DFB outbreak along the North Fork has had significant impacts, while in the Wiggins Fork area is just getting started. Much of the landscape along the North Fork is changed significantly. Land management objectives may have already been compromised along this area. Any remaining stands that are uninfested or lightly infested should be thinned and/or sanitized as soon as possible, if this meets management objectives. Sanitation should continue in and around administrative sites. In the Wiggins Fork area, an aggressive thinning and sanitation program should be undertaken if maintaining Douglas-fir stands in this area is desired. In either case, actions should be implemented as soon as possible to reduce tree mortality.

2. Use of protective treatments.

Use of MCH as a preventative should be continued in high value, administrative areas. MCH has been very effective at preventing DFB attacks in these areas and while the outbreak is still in progress, these areas should be protected. Table 2 lists known high value areas along the North Fork corridor and the needed amount of MCH to provide for tree protection (30/acre).

Table 2. Candidate areas, acreage, and estimated number of anti-aggregant capsules needed for treatment to prevent infestation by Douglas-fir beetle within US Forest Service campgrounds, permittee sites, and summer homes along the North Fork of the Shoshone River corridor, Wyoming

Candidate for Treatment	Acreage	MCH capsules needed
Newton Creek Campground	25	750
Eagle Creek Campground	9	270
Clearwater Campground	5	150
Permittee sites (9 total)	107	3,210
Summer homes	64	1,920
TOTAL	210	6,300

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